International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD)
ISSN(P): 2249-6866; ISSN(E): 2249-7978
Vol. 5, Issue 1, Feb 2015, 31-38
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SAFETY ANALYSIS OF WORK SPACES BY LOCATING MATERIALS IN BUILDING CONSTRUCTION SITES

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ABSTRACT

A building construction site has many unsafe and dangerous factors such as an elevator pit, a slab opening for lifting forms and materials. Accidents happen unpredictably though warning and caution signs for the dangerous factors provide safe working environment to workers. The warning signs are likely to be hidden by stacked materials or temporary facilities on site. The workers cannot notice the signs when moving or working. This paper suggests a method to identify a problem that the workers can't see the unsafe factors, and to manage the problem in construction planning phases with a worker's view using a CAD software.

KEYWORDS: Construction Safety, Work Space, Stacked Material, Temporary Work

INTRODUCTION

According to KOSHA [1], the number of workers and fatal injuries of all industries in 2011 are shown Table 1. The fatal injuries in construction industry are 621 persons (29.38%) and they are very larger than those of mining industry (375 persons, 17.74%). FRTTY (number of fatal rate per 10,000 workers in a year) of construction industry is 2.01, and it is larger than all industry (1.47) and manufacturing (1.64). Table 2 shows fatal and non-fatal injuries in construction industry. Various types of safety accident happened. Among them, the number of fall and drop (7,489 persons) is the highest, the second is slip and tip (4,191 persons), and the third is flying object (3,123 persons). The fatalities are 311 persons in fall and drop, 50 persons in crush, and 33 persons in flying object except illness. Fall and drop accidents accounted for over 50% of all fatalities.

Table 1: Fatalities in 2011

Industry	No. of Workers (Persons)	No. of Fatalities (Persons)	FRTTY*	Ratio (%)
Total	**14,362,372**	**2114**	**1.47**	**100.00%**
Construction	3,087,131	621	2.01	29.38%
Mining	12,088	375	310.23	17.74%
Manufacturing	3,333,131	548	1.64	25.92%
Electricity, Gas & Water supply	54,759	4	0.73	0.19%
Transportation, storage, & communication	719,488	134	1.86	6.34%
Forestry	93,815	20	2.13	0.95%
Fishing	3,378	4	11.84	0.19%
Agriculture	40,017	9	2.25	0.43%
Financing & Insurance	624,816	18	0.29	0.85%
Etc	6,393,750	381	0.6	18.02%
* FRTTY: No. of Fatal Rate per 10,000 workers in a year				

Table 2: Injuries/Fatalities and Accident Types in 2011

Type	Injuries (Persons)	Ratio (%)	Fatalities (Persons)	Ratio (%)
Total	**22,782**		**621**	
Fall & Drop	7,489	32.90%	311	50.10%
Slip & Trip	4,191	18.40%	32	5.20%
Collision	1,971	8.70%	22	3.50%
Flying object	3,123	13.70%	33	5.30%
Crush	452	2.00%	50	8.10%
Impacted fracture	1,856	8.10%	23	3.70%
Cut, Puncture	1,912	8.40%	1	0.20%
Electric shock	176	0.80%	22	3.50%
Explosion	49	0.20%	7	1.10%
Traffic accident	222	1.00%	37	6.00%
Illness	595	2.60%	44	7.10%
Improper action	444	1.90%	0	0.00%
Etc	302	1.30%	39	6.30%

There are many dangerous factors to safety accidents of falling, sliding, or collision in a construction site. Warning and caution signs provide workers with safe working environment. Temporary facilities and materials used for interior works would prevent the workers from noticing the warning sign and the dangerous factor. The sign or the dangerous factor couldn't be seen if the worker moves. For example, an elevator core is very dangerous to cause falling accidents, thus a warning sign is necessary in front of the elevator core. A worker cannot see the warning sign owing to stacked materials such as bricks, windows, and doors.

The stacked materials in a construction site are not causes to safe accidents, but they raise the probability of safety accident, because they make it difficult that a worker finds dangerous factors. This research proposes a method to analyze the location, height, and width of stacked material for construction workers to find dangerous factors continuously. The research uses a CAD software to show the relation between the stacked materials and the dangerous factors.

LITERATURE REVIEW

Safety Management Regulations

There are legal regulations to prevent safety accidents in construction sites. Occupational Safety and Health Act (No. 10968, July 25, 2011) regulates that every business shall assign a person in charge of safety and health management in Article 13, a person in general charge of health and safety for the purpose of the general control over the prevention of industrial accidents in Article 18, a supervisor in Article 14, and a safety officer in Article 15. The kind and scale of businesses in which safety officers are to be appointed, and the number of safety officers and the method of designation of safety officers shall be as specified in Enforcement Decree of the Occupational Safety and Health Act (No. 23845, June 7, 2012).

Safety facilities and equipments for a construction project are prescribed by the Standards on the Recognition and Usage of Funds for Occupational Health and Safety Management in the Construction Industry. The amount of the contract or work expenses determines the funds for occupational health and safety management (hereinafter, safety funds). Safety funds are used for the salary and allowance of safety officer, expenses of safety equipment, the inspection and improvement of working environment, the safety and health education of workers, the medical examinations of workers, and so on. Furthermore, safety funds should be disbursed according to the progress of construction work.

Related Studies

Many safety accidents occur in a construction site. Fall and drop is a major accident so many studies have focused on removing its causes. A research [2] showed that fall and drop accident occurs most frequently according to the analysis of scaffolding types and accident types. The research proposed a safety net, a joint between scaffoldings and the building being constructed, and so on to reduce the accidents. A paper [3] investigated severe fall accidents in temporary works, and indicated improper and inefficient safety management system in construction sites. The paper suggested that the installation and malfunction of temporary facilities, the method of temporary works, and the contents of the contract should be improved. An analysis [4] found that the causes of fall accident were employment status, period of continuous employment, when to work, tasks to work, unstable behavior, and unsafe environment. But it didn't show a specific alternative. The influence network [5] was used to analyze various causes of fall accidents, and found the paths between effect factors in order to reduce the safety accidents.

Recently, there are several efforts to prevent safety accidents using information technology. Studies [6, 7] developed the warning systems using real-time GPS (global positioning system) to warn workers when they were near dangerous areas. The studies need more accuracy of a worker's position in a construction site. RFID (Radio Frequency Identification) based real-time locating system [8] showed that safety management level could be raised by information technology and GPS, but jamming to locate a worker's position might be a problem.

SAFETY ANALYSIS BY MATERIAL LOCATION

Material Stacking

When a building is constructed, diverse materials are stored inside and outside the building. Steel bars are stacked outside, and lifted to install. Some bars are prefabricated before lifting. A system form like Gang form installed doesn't need a storage site because it is lift and re-installed by a crane. Euro forms and temporary equipments are stacked and used inside the building, then are moved to an upper floor through stairs or openings in the floor.

Bricks, blocks, or gypsum boards for interior walls are stacked inside the building. Windows and doors are also stored inside. These materials are stacked so high that a worker cannot see dangers behind the stacked materials. Every space without paths and work places is used for storage. The storage sites with materials may interrupt the paths and hide the dangerous positions and places.

Visibility Ratio

Dangerous factors can't be seen depending on the location of stacked materials and a worker's position. Figure 1 shows an elevator hall partially hided by the stacked materials. This research propose a method to solve this blindness problem using a CAD (computer aided design) software. After a worker's path and the location, height, and width of stacked materials are arranged on a drawing, a perspective view at the worker's position provides how much the dangerous factor is hided.

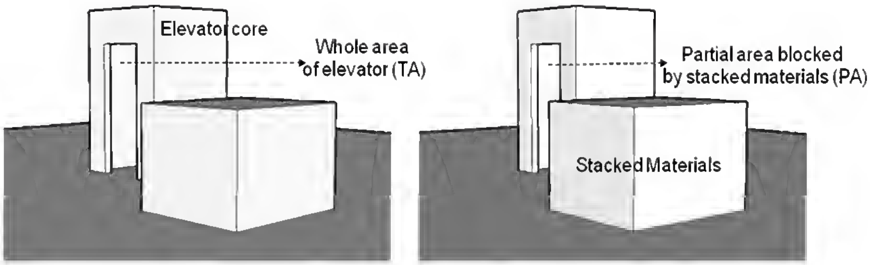


Figure 1: Worker's View on a Site

An equation is suggested to analyze visual area depending the distance between a dangerous factor and a worker's position. Visibility Ratio (VR) is defined as a ratio of visible part (PA) of the dangerous factor over total area (TA) of the dangerous factor without any obstacle. The further the distance of the worker's viewpoint and the dangerous factor, the less the visible area of the factor is. So, this research uses the ration instead of the areas.

VR = PA / TA

VR = Visibility Ratio (%)

PA = Partially visible area of a dangerous factor hided by obstacles

TA = Total visible area of a dangerous factor without any obstacle

VR is calculated and changed by the dangerous factor, the stacked material, and the worker. The locations of openings on a slab can be changed, but the elevator core cannot be moved. It is slightly difficult to change a worker's position because it is on a path or a work place. Otherwise, the location, width, and height of stacked materials is easily changed. If the materials are stacked on a site, it is not easy to move them to other place until they are totally installed. In order to raise VR, the location, width, and height of stacked materials should be determined by a construction manager in a planning phase. This makes the construction site safer.

Case Study

An office building plan is used to analyze VR shown in Figure 2. The office building has 5 floors and the plan is for 3rd to 5th floors. The building core is on the center of the plan and has an elevator pit. The exterior walls are made of reinforced concrete with stones and glass curtain walls. Interior works and windows installation follow the exterior wall. Interior walls are made of bricks and gypsum boards. They are stacked inside the building. Supposing bricks are stacked 4.0m wide, 4.0m long and 1.5m high inside the interior walls that are not installed yet, a worker behind the stacked material couldn't see all part of the elevator.

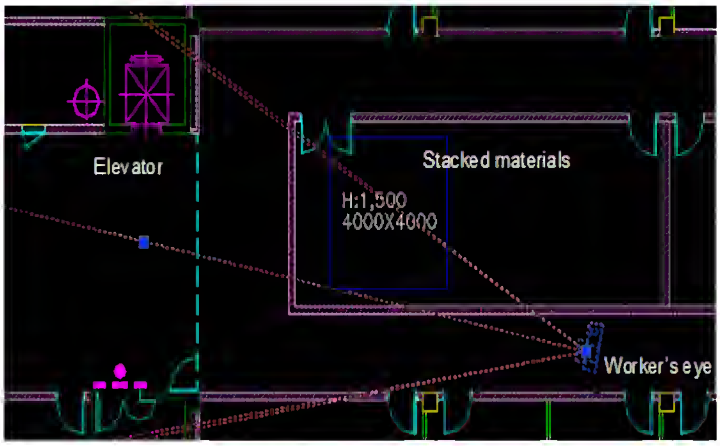
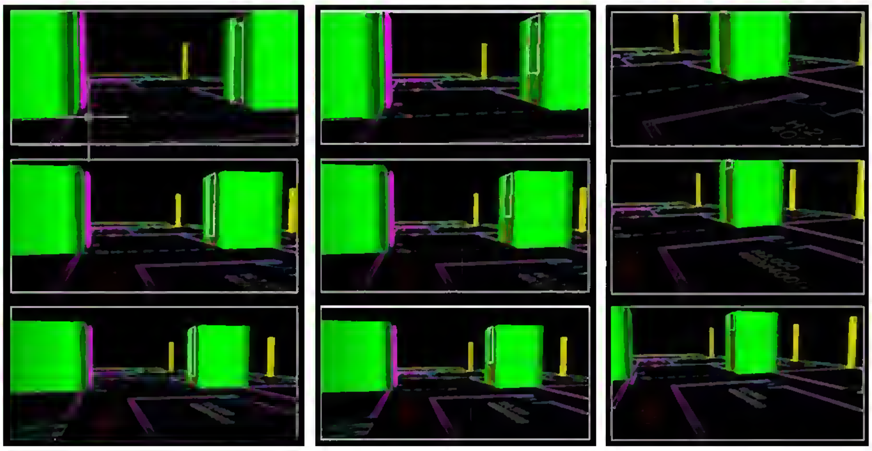


Figure 2: Locations and Scales of Stacked Materials

Figure 3 shows the perspective views at the elevator on the worker's different positions. The worker can see part of the elevator due to the stacked materials. The height of the stacked materials is changed in order to analyze the VR. The height of the stacked materials is 1.0m shown in Figure 3(a), 1.5m in 3(b), and 2.0m in 3(c) respectively.



(a) Height = 1.0m **(b) Height = 1.5m** **(c) Height = 2.0m**

Figure 3: Locations and Scales of Stacked Materials

The VRs are measured shown in Figure 4, in case the worker's eye-level is at 174cm high. The VR is about 29% when the height of the stacked materials is 2.0m higher than the eye-level. As the distance between the worker and the elevator is shorter than 15m, the VR is so low that the worker cannot see most of the elevator. But, in case of the height of the stacked materials is 1.0m or 1.5m below the worker's eye-level, the shorter the distance is, the higher the VR is.

The results show that as the height of the stacked materials is lower, the dangerous factor can be seen more, and as the distance between the worker and the dangerous factor is longer, the VR becomes lower. In addition, The VR changes a little as the distance is longer.

It is best to locate materials that don't hide a worker's view because the location of the stacked materials makes effect on the VR. But, a construction site has limited space to store materials so that it is difficult to lower the height of the stacked materials. In this case study, only one location and one path are analyzed. Further studies with several locations and paths at a time are necessary to enhance the safety in a construction site.

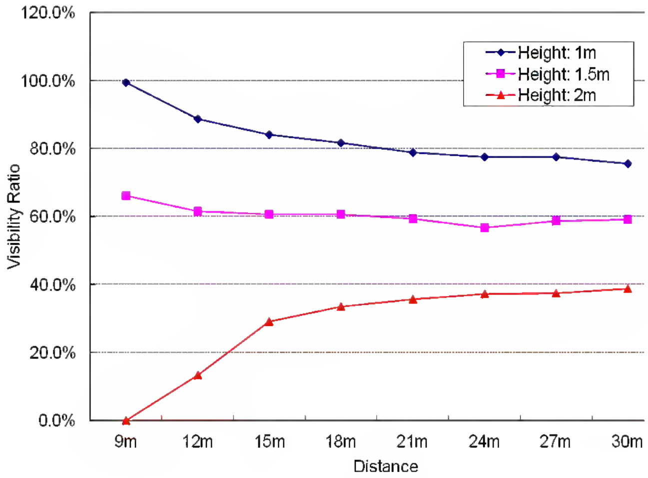


Figure 4: Visibility Ratio

CONCLUSIONS

There are many efforts to prevent safety accidents happened in construction sites. Some have proposed safer facilities and equipment, others have used information technology. This research focuses on the problem that stacked materials hide dangerous factors from a worker's view and suggests a method to analyze the worker's visibility using a CAD software. The results as follows:

- Materials, equipments, and facilities are the obstacles that hide the dangerous factors from workers. Their location, height, width, and length make an effect on the worker's visibility.
- Perspective plans at the worker's viewpoint are used to analyze VR (visibility ratio). In order to raise VR values, the height of the stacked materials should be lowered, or the location should be moved.

ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology. Grant No. 2010-0011139.

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